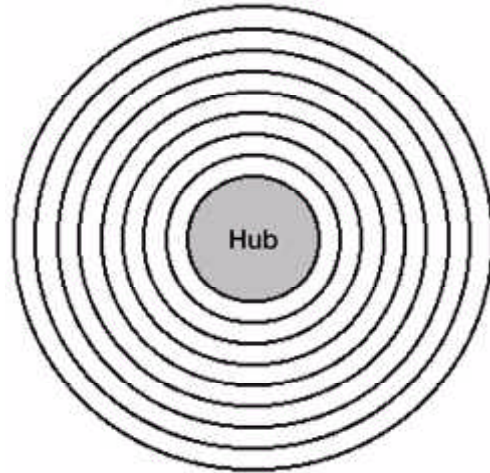


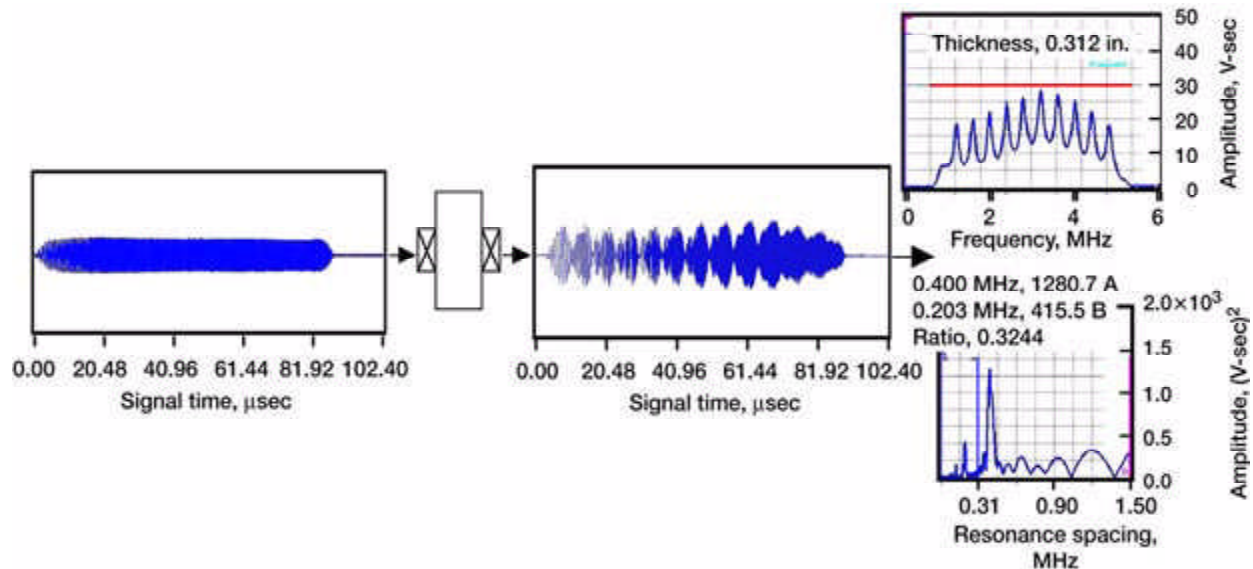
# New Approach to Ultrasonic Spectroscopy Applied to Flywheel Rotors



*Simple rotor--metallic hub with a rim consisting of eight concentric rings.*

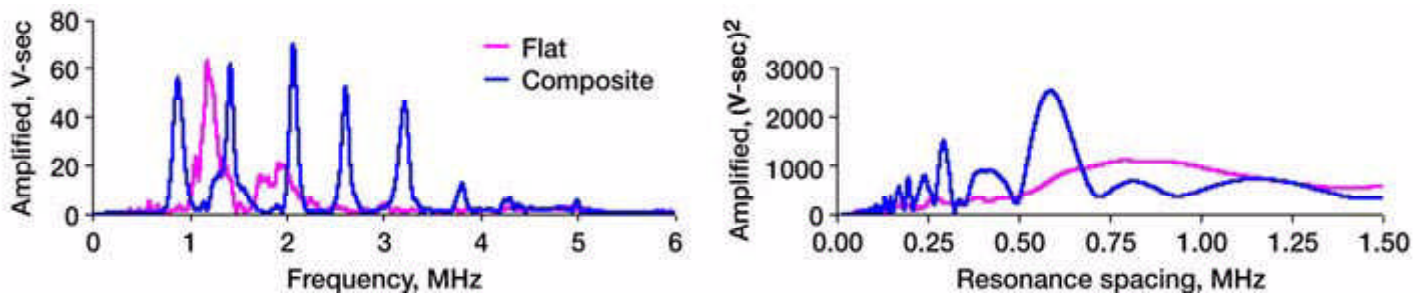
Flywheel energy storage devices comprising multilayered composite rotor systems are being studied extensively for use in the International Space Station. A flywheel system includes the components necessary to store and discharge energy in a rotating mass. The rotor is the complete rotating assembly portion of the flywheel, which is composed primarily of a metallic hub and a composite rim. The rim may contain several concentric composite rings (see the preceding figure). This article summarizes current ultrasonic spectroscopy research of such composite rings and rims and a flat coupon, which was manufactured to mimic the manufacturing of the rings.

Ultrasonic spectroscopy is a nondestructive evaluation (NDE) method for material characterization and defect detection (refs. 1 and 2). In the past, a wide bandwidth frequency spectrum created from a narrow ultrasonic signal was analyzed for amplitude and frequency changes. Tucker developed and patented a new approach to ultrasonic spectroscopy (ref. 3). The ultrasonic system employs a continuous swept-sine waveform and performs a fast Fourier transform on the frequency spectrum to create the spectrum resonance spacing domain, or fundamental resonant frequency (see the following figure). Ultrasonic responses from composite flywheel components were analyzed at Glenn to assess this NDE technique for the quality assurance of flywheel applications.



*Through-transmission ultrasonic spectroscopy on a Lucite sample. Left: Digital input waveform in the time domain. Center: Digital output waveform in the time domain. Right: Typical output display of the spectrum and spectrum resonance spacing domains. Long description Left: Frequency increases as time increases. Center: Output signal after ultrasound travels through the material. Right: Output display of the system with the spectrum and the spectrum resonance spacing.*

Amplitude and frequency changes in the spectrum and spectrum resonance spacing domains were evaluated from the ultrasonic responses of a flat composite coupon, thin and thick composite rings, and a multi-ring composite rim (refs. 4 and 5). Full-thickness resonance was produced in defect-free composite rings. The presence of foreign materials and of delaminations in composite rings were detected as an amplitude reduction in the spectrum domain and a change in fundamental resonant frequency. Manufacturing variations between the flat composite coupon and composite rings were detected as major differences in the response signals (see the final graphs). The presence of discrete and clustered voids with widths greater than 1.7 mm (0.07 in.) was detected in thick composite rings as an amplitude reduction in the spectrum and spectrum resonance spacing.



*Response from a flat composite coupon compared with the response from a composite ring. Left: Spectrum. Right: Spectrum resonance spacing.*

A unique detection of kissing disbonds requires further investigation, as their existence in composite rings was not confirmed destructively or corroborated with other nondestructive techniques. Voids with a width of 1.5 mm (0.06 in.) or smaller were not detected in the multi-ring composite rim. The ultrasonic responses before and after proof spin testing contained the same resonances for the four outer rings, suggesting that damage was not introduced to the rim. As a result, the signals from the multi-ring composite rim are baseline signatures to be compared after fatigue testing. On the basis of these findings, ultrasonic spectroscopy is a potential NDE tool for flight certification of flywheel rotors for the International Space Station.

## References

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